

Coupled Mineralogic Reaction and Isotopic Exchange in Regionally Metamorphosed Dolomite, Death Valley, California

Theodore C. Labotka (tlabotka@utk.edu)¹, Peter Souza¹ & Peter Nabelek²

¹ Dept. of Geological Sciences, University of Tennessee, Knoxville, Tennessee, 37996-1410, USA

² Dept. of Geological Sciences, University of Missouri, Columbia, Missouri, USA

The Upper Proterozoic Noonday Dolomite in the Panamint Mountains, near Death Valley, California, was regionally metamorphosed under low-pressure, high-temperature conditions during Mesozoic time. The rocks were also deformed during Tertiary extension, which was accompanied by local retrograde metamorphism. The upper section of the Noonday Dolomite consists of mostly dolomite with various amounts of quartz grains and is sandwiched between siliceous limestone below and pelitic schist above. We examined this unit along a nearly isothermal strike section to determine whether metamorphic fluids flowed across the layer or whether the dolomite acted as a relatively impermeable barrier to fluid flow.

Mineral assemblages in the dolomite are mostly dolomite + calcite + quartz + talc and dolomite + calcite + quartz + tremolite. Some samples contain both talc and tremolite. In retrograded samples, tremolite is altered to a fine-grained mixture of talc and calcite, and the rock texture is a mylonite. Calcite Mg compositions are consistent with a temperature of 475 °C, which is consistent with the fluid-composition buffering assemblage at a pressure of 250 MPa over a range in fluid composition from X = 0.1 to 0.6.

The carbon-isotope composition of dolomite shows a large range from $\delta^{13}\text{C}_{\text{PDB}} = +8.0$ to -3.0 ‰, most of which is inherited from the protolith. Retrograde calcite is less than 0.5‰ lower than the prograde calcite. The oxygen-isotope composition of calcite and dolomite ranges from $\delta^{18}\text{O}_{\text{SMOW}} = 24.0$ to 18.5 ‰. Retrograde calcite is 3.0 ‰ lower than the prograde. There is a correlation between the isotopic compositions of calcite and

dolomite in both oxygen and carbon, which could be a result of closed-system metamorphism of rocks with initial variability in isotopic composition. However, the oxygen-isotope composition of dolomite decreases with a decrease in the abundance of dolomite, and the composition of calcite decreases with an increase in the abundance of calcite. The oxygen-isotopic compositions of both dolomite and calcite decrease with an increase in reaction progress, ξ , as measured by the abundance of talc and tremolite (Fig. 1). The implication is that isotopic exchange and mineral reaction are coupled and that fluids with a low value of $\delta^{18}\text{O}$ reacted with the dolomite + quartz rock during metamorphism.

The maximum observed value of ξ in these rocks is 0.2 mol/kg, which in a closed system requires a porosity of ~2% to account for the abundance of talc and tremolite. Yet, the pressure generated in the pore space would cause the rock to fail at a value of ξ of only 0.001 mol/kg; fracture of the rock is required to allow access to the low $\delta^{18}\text{O}$ fluid. The extents of reaction are small and indicate reaction with only small amounts of externally derived H₂O (maximum amounts are ~ 0.8 mol/kg rock), yet the great decrease in $\delta^{18}\text{O}$ implies a very low ^{18}O source for the fluid. Simple mass balance calculation indicates that at the water/rock oxygen ratio of 0.02, indicated by the mineral reaction, the water had to have had an isotopic composition of 0 ‰. Mineral reaction appears to have been driven by external fluid, which, in turn, had greater access to the rock by virtue of increased permeability caused by reaction. Even at 475°C, the dolomite was fractured and permitted ingress of isotopically light, perhaps meteoric water.

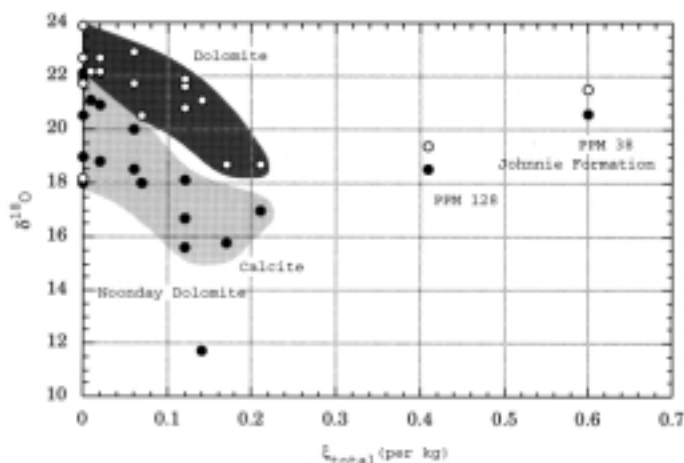


Figure 1. Composition of calcite and dolomite from the Noonday Dolomite, with some samples from the overlying Johnnie formation for comparison.